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An Empirical Analysis of Human Performance and Nuclear Safety Culture

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INTRODUCTION

The purpose of this analysis, which was conducted for the US Nuclear Regulatory Commission (NRC), was to test whether an empirical connection exists between human performance and nuclear power plant safety culture. This was accomplished through analyzing the relationship between a measure of human performance and a plant's Safety Conscious Work Environment (SCWE). SCWE is an important component of safety culture the NRC has developed, but it is not synonymous with it. SCWE is an environment in which employees are encouraged to raise safety concerns both to their own management and to the NRC without fear of harassment, intimidation, retaliation, or discrimination.

Because the relationship between human performance and allegations is intuitively reciprocal and both relationship directions need exploration, two series of analyses were performed. First, human performance data could be indicative of safety culture, so regression analyses were performed using human performance data to predict SCWE. It also is likely that safety culture contributes to human performance issues at a plant, so a second set of regressions were performed using allegations to predict HFIS results.

DESCRIPTION OF ACTUAL WORK

The human performance data was obtained from the NRC's Human Factors Information System (HFIS). The HFIS database provides a general overview of the types and approximate numbers of human performance issues documented by the NRC or licensees. Data indicative of SCWE were obtained from the NRC allegations database. While these data sources may not be the most complete measures of either human or plant safety, we believed they were sufficient for use in this exploratory investigation.

Allegations data were only available from the years 2001 through 2004. HFIS data were available by unit while the allegations data obtained were aggregated by site. Hence the HFIS data were combined and a total of 64 sites were analyzed from 2001 to 2004.

RESULTS

The nonparametric Kendall's Tau correlations of the allegations and HFIS hits by year showed a number of significant correlations at the $p = 0.05$ level. This

indicated a general degree of association or predictability between these variables. However, as expected, there were a number in instances where allegations in one year were autocorrelated with allegations in the following year. Moreover, these data are count data, which do not necessarily meet the usual assumptions (e.g., additivity of effects, normality, equal variances) associated with the standard tests. To analyze these count data further, we assumed a Poisson distribution, and used a log-Poisson regression model. Log-Poisson models are one type of a broad class of models called generalized linear models. An introductory discussion of generalized linear models and log-Poisson models can be found in [1].

Results of the log-Poisson model analyses for the dependent variable allegations showed that, most of the time, even after controlling for the previous year's allegations, the previous year's HFIS data significantly predicted allegations for the following year. For example, the 2003 HFIS data significantly predicted 2004 allegations even after controlling for the effects of the 2003 allegation data (Wald = 7.64, $p < .01$). 2001 HFIS data significantly predicted 2002 allegations even after controlling for the effects of the 2001 allegation data (Wald = 3.94, $p < .05$). These results held true in some follow-up analyses where subsets of the data were used to test ancillary hypotheses about the strength and specificity of the ability of HFIS data to predict allegations.

The opposite relationship, where allegations in an initial year are used to predict HFIS hits in the following year while controlling for the HFIS hits in the initial year was also tested. A number of significant results using the log-Poisson model analyses were obtained. 2001 allegations data significantly predicted 2002 HFIS findings even after controlling for the effects of the 2001 HFIS data (Wald = 5.68, $p < .02$). 2002 allegations data significantly predicted 2003 HFIS findings even after controlling for the effects of the 2002 HFIS data (Wald = 12.18, $p < .01$). 2003 allegations data significantly predicted 2004 HFIS findings even after controlling for the effects of the 2003 HFIS data (Wald = 10.208, $p < .01$). Follow-up analyses to test ancillary hypotheses about the strength and specificity of the ability of allegations data to predict HFIS hits also yielded a number of significant results.

CONCLUSION

These preliminary analyses provide basic support for the premises that human performance data can predict aspects

of nuclear power plant safety culture, and that aspects of safety culture can predict human performance. We are encouraged by these results because they provide an empirical basis for the belief that, within the nuclear industry, human performance and safety culture are interrelated and that improving either involves using systemic approaches that take into consideration the complexities of their relationship. While it should be noted that this was a preliminary analysis that yielded promising results, more detailed studies are needed to improve the predictive capability of the models. We believe, however, the results obtained in this study using limited data justifies further effort in acquiring better data measures for more definitive modeling.

REFERENCES

1. A. AGRESTI, "*An Introduction to Categorical Data Analysis*," John Wiley and Sons, Inc., New York City, (1996).